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DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-88/18-02

Executive Summary

ASSESSMENT OF ROUTINE MAINTENANCE NEEDS  
AND OPTIMAL USE OF MAINTENANCE FUNDS:  
FINAL REPORT

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and

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PURDUE UNIVERSITY



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EXECUTIVE SUMMARY

ASSESSMENT OF ROUTINE MAINTENANCE NEEDS AND OPTIMAL USE OF ROUTINE  
MAINTENANCE FUNDS

TO: H. L. Michael, Director  
Joint Highway Research Project

August 31, 1988

FROM: Kumares C. Sinha, Research Engineer  
Joint Highway Research Project

Project No: C-36-63K

File: 9-7-11

Attached is the Final Report on the HPR Part II Study entitled, "Assessment of Routine Maintenance Needs and Optimal Use of Routine Maintenance Funds." This report presents the results of all phases of the study including recommendations for implementation. The draft dated August 31, 1988 was submitted to the members of the Advisory Committee for review and the comments of the IDOH representative in the Committee have been incorporated in the current version. This report was prepared by me and the research work was conducted by Messrs. F. M. Montenegro, K. J. Feighan, R. P. Tandon, K. Ksaibati and T. Al-Suleiman and Drs. T. F. Fwa and J. D. N. Riverson under my direction.

The report is forwarded for review, comment and acceptance by the IDOH and FHWA as fulfillment of the objectives of the research.

Respectfully submitted,



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Executive Summary

ASSESSMENT OF ROUTINE MAINTENANCE NEEDS AND OPTIMAL USE  
OF ROUTINE MAINTENANCE FUNDS

by

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Joint Highway Research Project  
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in cooperation with the

Indiana Department of Highways

and the

U.S. Department of Transportation  
Federal Highway Administration

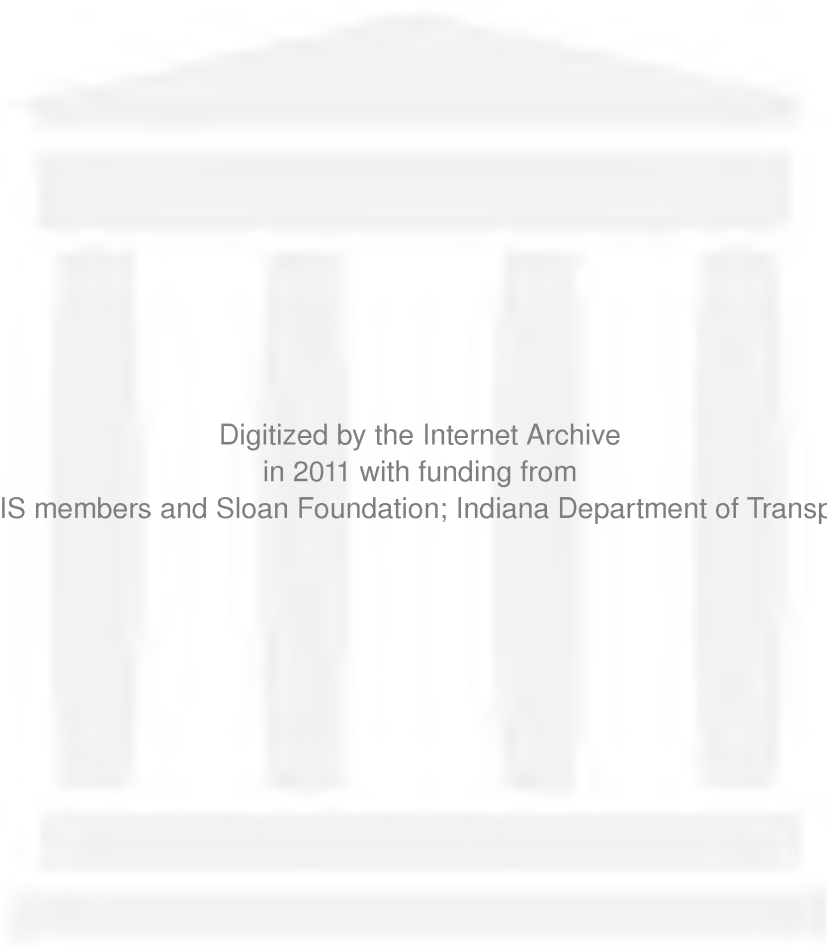
The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or a regulation.

Purdue University  
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16. Abstract <p>This report presents the findings of a research work on the development of optimal strategies for highway routine maintenance management. A procedure based on a condition survey was developed for the assessment of maintenance needs at the subdistrict level. An expert system was developed to illustrate how the procedure can be programmed to facilitate easy implementation. A possible design of an integrated routine maintenance data base system was prepared so that data related to pavement roughness and rehabilitation schedules could be integrated with highway characteristics, traffic and other data for maintenance management. In order to ascertain what type of surface condition data to be included in the data base, an analysis was performed to investigate the relationship between routine maintenance and surface roughness. Two separate surveys of maintenance personnel were conducted to estimate information on cost and service life of various maintenance activities as well as to determine perceived priorities for these activities. An optimization model was then developed that can be used for programming and periodic scheduling of maintenance activities within the constraints of budget and other resources. The report also includes recommendations for implementation.</p>			
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## BACKGROUND INFORMATION

An area of major concern for highway agencies today is routine maintenance. In recent years, due to the impact of high inflation and fiscal restraint, most state highway agencies cannot afford to maintain their highways to the standard practiced in the 1960s when the highway system was relatively new. Today, as more and more of the highways built during the 1950s and 60s are reaching and passing their original design life, the need for maintenance and rehabilitation is growing more rapidly.

With the view of combating the problem of deteriorating highway system, the Federal 3-R (Resurfacing, Restoration and Rehabilitation) Program was launched in 1976. In 1982, a fourth R, Reconstruction, was added with a substantial increase in Federal funding. Also, there was a significant increase in Federal matching grant for several states due to "the 85 percent floor" clause of the STAA of 1982. Despite these efforts to increase highway funds, the basic problem of needs exceeding available revenues still remains. Most importantly, the use of Federal grant in improvement projects of 4R type requires state matching money. Furthermore, there is no Federal money available for routine maintenance. Consequently, the need to allocate optimally the fund available for routine maintenance is ever present.

The emphasis in highway activity is now on protecting as well as prolonging the service life of existing facilities. Under a situation where available resources are limited and insufficient to meet total funding needs to match Federal grant as well as to finance entirely state supported activities, an effective management approach performs a vital role.



Most states and numerous other agencies have installed separate maintenance management and pavement management systems. A pavement management system (PMS) generally involves the preservation of physical condition of existing pavements, while a maintenance management system (MMS) involves the management of resources for routine maintenance of pavement, shoulder, drainage and other highway elements. An effective highway management approach would be to integrate maintenance aspects in pavement management and to widen the role of MMS so as to consider facility management approach in routine maintenance decisions.

#### SCOPE OF THE STUDY

The purpose of the present study was to develop a systematic methodology that can provide optimal strategies for highway routine maintenance management. The optimality was to be measured in terms of the level of preservation of the condition of various highway elements. In this effort, several tasks were undertaken as depicted in Figure 1. There were two major tasks, the assessment of maintenance needs and the development of an optimization model for programming of maintenance activities. A procedure based on a condition survey was developed for the assessment of maintenance needs at the subdistrict level. An expert system was developed to illustrate how the procedure can be programmed to facilitate easy implementation. A possible design of an integrated routine maintenance data base system was prepared so that data related to pavement roughness and rehabilitation schedules could be integrated with highway characteristics, traffic and other data for maintenance management. In order to ascertain what type of surface condition data to be included in the data base, an analysis was performed to investigate the relationship





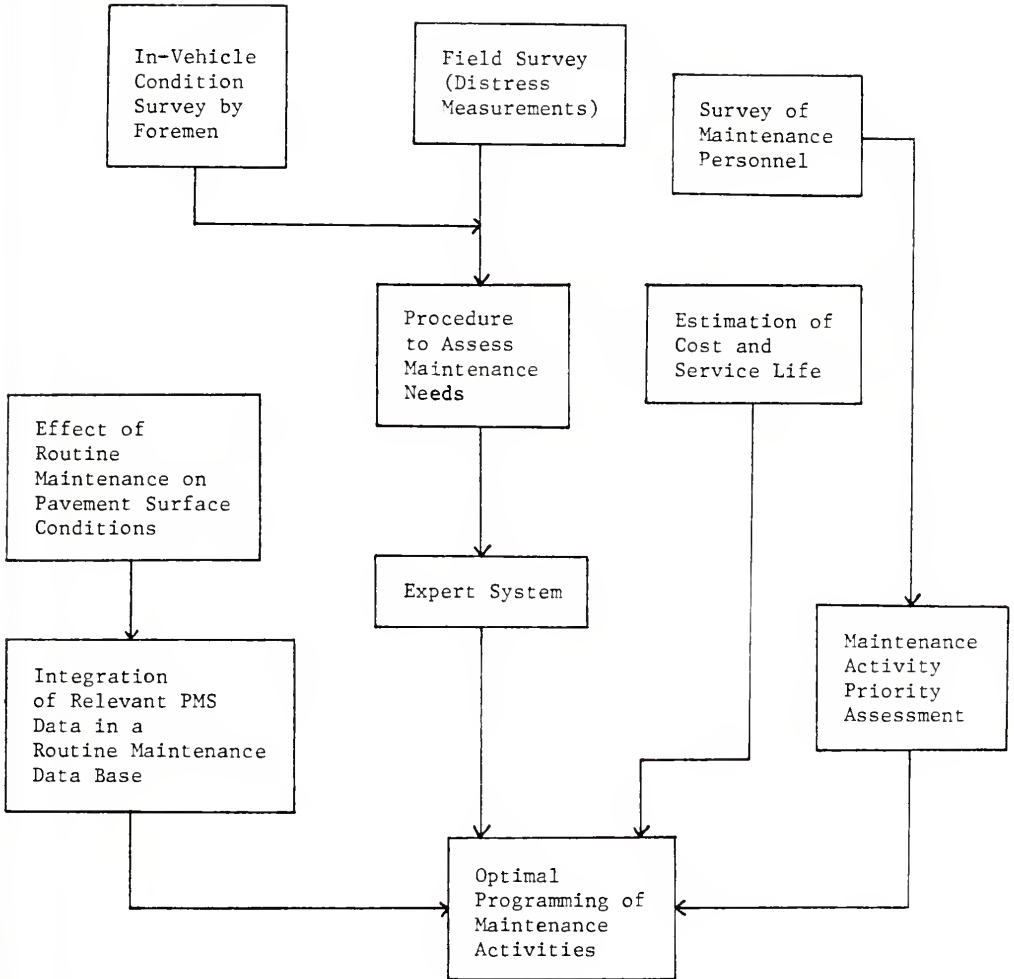


Figure 1. Schematic Diagram Showing Basic Elements of the Study



between routine maintenance and surface roughness. Two separate surveys of maintenance personnel were conducted to estimate information on cost and service life of various maintenance activities as well as to determine perceived priorities for these activities. An optimization model was then developed that can be used for programming and periodic scheduling of maintenance activities within the constraints of budget and other resources. A more descriptive summary of each stage of the study is presented in the following sections.

#### Procedure to Assess Routine Maintenance Needs

A procedure was developed that can be used to estimate routine maintenance work loads by highway section during a coming year or season. Although the approach can also be extended for maintenance budget planning, the primary area of application of the proposed procedure is in determining how much maintenance work needs to be undertaken in what highway sections within a subdistrict. The procedure would be based on periodic survey of highway distresses by unit foremen and then subsequent use of a set of quantity standards, termed as "present quantity standards." These standards were developed by relating the foremen's subjective ratings of road conditions to objective measurements of distresses in the field and subsequent transformation of subjective ratings to expected work loads. A statistical regression analysis was used to develop the necessary relationships. The field data were collected from eighteen randomly selected maintenance units in Indiana.

#### Estimation of Service Life and Cost of Maintenance Activities

The information on service life and cost is necessary primarily to



identify cost-effective solutions as well as to monitor if change in work practices or materials significantly influences the activity effectiveness. The routine maintenance activities considered were from the general areas of pavement, shoulder and drainage maintenance. The unit cost information per production unit was obtained from an analysis of crew day card reports. The service life data were developed through a personal interview with subdistrict foremen using a questionnaire approach. The estimates of service life were related to the condition as well as to the accomplishment per day. The resulting information provides a reasonable set of input data to the optimization of maintenance decisions.

#### Effect of Routine Maintenance on Pavement Roughness

In order to determine if pavement surface roughness data collected routinely can be used to make maintenance decisions, a study of the relationship between routine maintenance expenditure level and pavement roughness was conducted. A data base by contract section was developed for the state highway system of Indiana. Covariance analysis was performed to test the effect of climatic region. Regression models were developed to examine the effect of routine maintenance expenditure level on rate of change in pavement roughness. Two highway classes and three pavement types were considered in the analysis. The data base included a total of 550 pavement contract sections. The results indicated that roughness information can be used to develop an effective maintenance program.

#### The Configuration of a Pavement Routine Maintenance Data Base System

When developing a routine maintenance management system, the creation



of a meaningful data base should be considered. A microcomputer data base was developed that can be used at different maintenance management levels of the Indiana Department of Highways. Condition survey information, based on unit foremen's evaluation of highway deficiencies, may be included in the proposed data base. The condition survey information along with roughness measurements can be used in two ways. First, the Central Office can use the information in programming maintenance and improvement activities. Second, the data can be used by subdistricts to set priorities for routine maintenance work on highway sections within their jurisdiction. Information on improvement activities, such as resurfacing, was included in the data base to increase the level of coordination between the programming of improvement and routine maintenance activities. This coordination may result in substantial savings in pavement maintenance and improvement. Some other supplementary information, such as average daily traffic, contract number, county, subdistrict, and pavement type was included in the data base. A pilot implementation plan is proposed. Performance of the data system in pilot implementation should be evaluated to provide the feedback necessary to assess the value of information included in the data base.

#### An Expert System to Estimate Highway Pavement Routine Maintenance Work Load

An expert system was developed that can be used to estimate highway pavement routine maintenance needs at a subdistrict level. The knowledge base was prepared on the basis of the judgment of unit foremen extracted from the survey mentioned earlier. The expert system is written in LISP





and is interactive in nature. It requires the user to input information about the general features of the highway section and the observed distress data. The package gives explicit recommendations as to the type and amount of activities to be performed along with the information on expected costs. The current version of the system deals only with routine maintenance activities on flexible pavements.

#### Priority Rating of Routine Maintenance Activities

A procedure was developed for determining priority ratings of highway routine maintenance activities by highway class and distress condition. In contrast to the common practice of assigning priority ratings based on an aggregated pavement condition index, a scheme that generates maintenance activity specific priority ratings was adopted. Since there exists a large number of maintenance activity-highway class-distress severity combinations to be rated, a partitioned two-stage survey procedure was adopted to reduce the number of factors in each rating phase to a size manageable by raters. This rating procedure was used to obtain priority factors for routine maintenance activities in Indiana. These priority data were incorporated into an optimal routine maintenance programming model proposed for use at the district and subdistrict levels of the Indiana Department of Highways. An analysis was also made of the Indiana data to demonstrate how other useful information on routine maintenance practice could be derived from this form of study.

#### Optimal Programming of Maintenance Activity

A mathematical programming procedure for scheduling routine maintenance activities at network level was developed for incorporation into the



existing pavement maintenance management system of Indiana. The procedure allows a highway agency to determine amounts of different routine maintenance activity types to be performed over a given time period under the constraints of production requirements, budget allocation, manpower, material and equipment availability, and pavement rehabilitation schedule. A priority weighting factor is assigned to each maintenance work so that higher priority work would be selected for execution. Rehabilitation constraints are included to ensure proper coordination between the selected routine maintenance activities and planned rehabilitation projects. An integer programming optimization model was developed for the proposed procedure. The types of data required and their acquisition was discussed. A numerical example based upon routine maintenance information obtained from the Indiana Department of Highways was developed as an illustration.

#### RECOMMENDATIONS FOR IMPLEMENTATION

The study dealt with several elements of maintenance management systems. Not all of these can be immediately implemented. Nor can some of them be implemented without further developmental work. Again, some of the items may require additional manpower and accessibility to computers. Therefore, the implementation should take place in an incremental manner. First, the needs assessment procedure using the approach developed in the study can be implemented immediately in a selected set of subdistricts. A series of carefully planned training sessions will be necessary to acquaint the subdistrict personnel with the procedure. The results obtained from the proposed procedure should be used as a complement to the currently used procedure to estimate maintenance needs. Once the procedure appears to produce useful results, more subdistricts can be



included. At some point, the standards will have to be updated and a larger sample of subdistricts can be used to estimate the updated standards. As the unit foremen become used to the idea of the condition survey based procedure, the variation in opinion among unit foremen would be minimized and a highly consistent set of standards can be developed. It is believed that the implementation of the procedure using the standards developed in the study would require very little additional manpower, because a periodic condition survey is already a part of the current maintenance management practice in Indiana. The only additional effort would be to record the information in a systematic manner and to make the necessary need estimates. The estimates can be made using the expert system (for flexible pavements) or using the charts provided in the interim report [Montenegro and Sinha 1986].

An immediate use can be made of the information on service life and cost of maintenance activities [Feighan et al. 1986]. By examining the relative cost and effectiveness of performing maintenance alternatives using various materials and equipment under different roadway conditions, the current practices can be evaluated in terms of their cost-effectiveness. Possible changes can then be instituted, if necessary, in maintenance practices of various subdistricts.

The next item that can be implemented, in the short term, is the optimization model [Fwa et al. 1988]. The present vision of the model will require the use of the mainframe computer. Although the model requires a large amount of data, they are currently available within the IDOH or as a result of the present study. Once implemented, most of the required data would be fixed and the variable data would include such



items as production requirements, budget and other constraints. Initially, it is recommended that the model be implemented in a selected district in order to verify the usefulness of the model and to acquaint the prospective users with the model operation. Although the model will be run at a district office, the data can be specific to a number of selected subdistricts within a district. The results generated by the model can be compared with the manually prepared schedules for monitoring the performance of the model. At some future date, when an integrated routine maintenance data base is implemented, most of the necessary input data for the optimization model would be directly available from the data base.

#### REFERENCES

- Feighan, K., Sinha, K. C. and White, T. D. [1986], "An Estimation of Service Life and Cost of Routine Maintenance Activities," Report No. FHWA/IN/JHRP-86/9, School of Civil Engineering, Purdue University.
- Fwa, T. F., Riverson, J. D. N. and Sinha, K. C. [1988], "Priority Assessment of Routine Maintenance Needs and Optimal Programming," Report No. FHWA/IN/JHRP-88/1, School of Civil Engineering, Purdue University.
- Montenegro, F. M. and Sinha, K. C. [1986], "The Development of a Procedure to Assess Highway Routine Maintenance Needs," Report No. FHWA/IN/JHRP-86/4, School of Civil Engineering, Purdue University.



















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